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DIET OF IMMATURE KEMP'S RIDLEY TURTLES (*LEPIDOCHELYS KEMPI*) FROM GULLIVAN BAY, TEN THOUSAND ISLANDS, SOUTHWEST FLORIDA

Wayne N. Witzell and Jeffrey R. Schmid

ABSTRACT

To examine the diet of immature Kemp's ridley turtles, 66 fecal samples were collected and examined for 64 turtles captured in Gullivan Bay, Ten Thousand Islands, southwest Florida. Prey items were placed into six main categories and the percent frequency of occurrence (FO) and percent dry mass (DM) were calculated: live bottom (83.3% FO, 38.6% DM); crabs (72.7% FO, 34.9% DM); unidentified (63.6% FO, 24.8% DM); mollusks (40.9% FO, 1.5% DM); vegetation (22.7% FO, 0.1% DM); and fish (1.5% FO, 0.0% DM). The major prey item in the live bottom category was a benthic tunicate (*Molgula occidentalis* Traustedt, 1883; 72.7% FO, 30.5% DM), and the two major prey items in the crabs category were spider crabs (*Libinia* spp.; 42.4% FO, 13.5% DM), and the purse crab (*Persephona mediterranea* Herbst, 1794; 37.9% FO, 8.3% DM). There were small differences in prey consumption between turtles < 40 cm MSCL and those > 40 cm MSCL. The consumption of benthic tunicates by Kemp's ridleys has not been reported in previous dietary studies, suggesting that they are opportunistic feeders taking advantage of an abundant food source. Environmental changes influencing the tunicate population in the Ten Thousand Islands (e.g., South Florida Restoration Project) could impact this unique predator-prey relationship.

The Kemp's ridley turtle (*Lepidochelys kempi* Garman, 1880) is the most endangered sea turtle in the world and relatively little is known about the ecology of immature turtles in coastal developmental habitats (National Research Council, 1990; Musick and Limpus, 1997). Dietary information of immature Kemp's ridleys has been derived from necropsies of stranded animals and fecal examination from captured specimens. Many reports of dietary items are from relatively small numbers of stranded turtles (De Sola and Abrams, 1933; Liner, 1954; Dobie et al., 1961; Hardy, 1962; Lutcavage and Musick, 1985; Bellmund et al., 1987; Dobie, 1996; Frick, 1997). More recently, studies involving substantially larger samples of necropsied turtles have been reported from Virginia (Seney, 2003), Georgia (Frick and Mason, 1998), upper Texas (Cannon, 1998), and south Texas (Shaver, 1991, 1998). Dietary studies based on fecal examinations have been less extensive than the stranding studies, and have been conducted in New York (Burke et al., 1993a,b, 1994; Morreale and Standora, 1998) and Texas-Louisiana (Werner, 1994). The results of these studies (necropsy and fecal) indicate that the Kemp's ridleys eat a plethora of organisms, ranging from crabs, gastropods, bivalves, and fish to insects, birds, and diamondback terrapins. There is even an aerial observation of ridleys feeding on the pectoral fins of swimming cownose rays, *Rhinoptera bonasus* Mitchill, 1815 (Frick et al., 1999). Nonetheless, the most commonly reported prey items are crabs (Table 1), particularly blue crabs (*Callinectes sapidus* Rathbun, 1896), and, as such, the Kemp's ridley is commonly referred to as being primarily cancivorous.

Differences in the frequency, abundance, and species of prey items selected by immature Kemp's ridley turtles may be influenced by turtle size, the geographic loca-

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Table 1. Reported frequencies and quantities of crab species consumed by immature Kemps ridley turtles.

Location	Mean carapace length (cm)	n	Crab species	% occurrence	% mass	Reference
Long Island Sound	32.3	19	*Libinia emarginata* Leach, 1815	58.0	60.0	Burke et al., 1994
			Cancer irroratus Say, 1817	36.0	22.0	
			Ovalipes ocellatus Herbst, 1799	16.0	18.0	
Chesapeake Bay	36.0	18	*Callinectes sapidus* M.J. Rathbun, 1896	72.2	21.7	Seney, 2003
			Libinia sp.	66.7	12.9	
			Persephona mediterranea (J.F.W. Herbst, 1794)	44.4	9.7	
			Pagarus sp.	33.3	0.2	
			Cancer irroratus Say, 1817	27.8	0.8	
			Ovalipes ocellatus J.F.W. Herbst, 1799	5.6	0.1	
Texas–Louisiana	33.1	79	*Callinectes* sp.	43.0	20.1	Werner, 1994
			Menippe sp.	4.7	3.6	
			Persephona sp.	1.2	0.2	
			Clibanarius vittatus Bosc, 1802	1.2	0.2	
South Texas	43.3	50	*Callinectes sapidus* M.J. Rathbun, 1896	44.0	9.3	Shaver, 1991
			Persephona sp.	40.0	11.5	
			Libinia sp.	32.0	11.4	
			Hepatus epheliticus Linné, 1763	28.0	7.2	
			Arenaeus cribarius (Lamarck, 1818)	30.0	21.9	
			Isocheles sp.	16.0	0.2	
			Menippe sp.	10.0	4.4	

tion, prey availability, and/or prey preference (Burke et al., 1993a,b, 1994; Werner, 1994; Shaver, 1991, 1998; Cannon, 1998). Information on the feeding habits of immature Kemp's ridleys is important for identifying critical developmental habitats and formulating recovery strategies. The present study examines the dietary regime of immature Kemp's ridleys captured in Gullivan Bay, Ten Thousand Islands, southwest Florida, using data derived from fecal samples of captured turtles.

Materials and Methods

Immature Kemp's ridley turtles were captured during a sea turtle survey conducted by the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC), in Gullivan Bay, Ten Thousand Islands, southwest Florida (Witzell and Schmid, 2004). A subset of 64 turtles captured during the 1999–2000 tagging seasons was taken to a shore-side facility and placed in shaded polyethylene holding tanks. The turtles were held for 24–48 hrs and all solid defecated materials were removed with a fine-mesh aquarium net, placed in plastic bags marked with date and flipper tag number, and stored at approximately −5 °C in a commercial freezer. Turtles were then measured, weighed, tagged, and released near the original point of capture. Carapace measurements are reported as minimum straight carapace length (MSCL: midline of nuchal scute to the posterior notch of supracaudals) unless noted otherwise.

The method used to process the samples was very similar to other major diet studies (Shaver, 1991; Burke et al., 1993a,b, 1994; Werner, 1994; Seney 2003). The fecal samples were thawed and washed through U.S. standard #4 (4.75 mm) and #200 (0.063 mm) sieves. Items retained by the # 4 sieve were sorted and identified to the lowest possible taxon using Gosner (1978), Voss (1976), and Williams (1984). Items passing through the #4 sieve and retained by the #200 sieve were classified as unidentified. Sorted prey items were placed in aluminum weighing dishes and dried in an oven at 80 °C for 24 hrs. Dry weight was measured to the nearest 0.01 g with an electronic scale. Percent frequency of occurrence (% FO) and percent dry mass (% DM) of each prey group were determined by:

% FO = (number of samples containing prey item/total number of samples) × 100

% DM = (dry weight of prey item/total weight of all prey items) × 100

The fecal data were grouped by turtle size class (< 40 cm MSCL and > 40 cm MSCL) to determine if different size turtles were consuming different prey items or different quantities of the same prey. Standard linear regression techniques were used to compare carapace length and the mass of fecal sample. All means are presented ± standard deviation (SD).

Results

Sixty-six fecal samples were obtained from 64 Kemp's ridley turtles. Two turtles were recaptured and therefore yielded two samples. Samples were collected from turtles held captive in April–September, 1999 and June–October, 2000, with two additional samples collected in May and November, 2002. Turtles ranged in size from 28.2 to 52.5 cm MSCL with a mean size of 41.4 ± 5.8 cm MSCL. The sample of turtles was representative of the Kemp's ridley aggregation that occurs in Gullivan Bay (Witzell and Schmid, 2004). Dry mass of the individual fecal samples ranged from 0.01 to 94.12 g with a mean dry mass of 19.15 ± 18.61 g. There appeared to be a positive trend between the carapace length of the turtle and the mass of the fecal sample, but the regression for these variables was not significant ($F = 2.92$, $P = 0.09$) due to considerable variation ($R^2 = 0.04$) in fecal mass by length.

Turtles consumed a variety of items (Table 2) that were grouped into six major categories (live bottom, crabs, mollusks, vegetation, fish, and unidentified). Within these major categories, there were three identifiable live bottom taxa, 12 crab taxa, seven mollusk taxa, five vegetation taxa, and one fish taxon. The live bottom category had the highest percent frequency of occurrence (83.3% FO) and the highest percent dry mass (38.6% DM), followed by the crabs (72.7% FO, 34.9% DM) and unidentified categories (63.6% FO, 24.8% DM). The live bottom category was dominated by the tunicate *Molgula occidentalis* Traustedt, 1883 (72.7% FO) that comprised 30.5% of the fecal mass for all samples. The crab category was primarily composed of *Libinia* sp. (42.4% FO) and *Persephona mediterranea* Herbst, 1794 (37.9% FO), and together contributed 21.8% of the fecal mass. The unidentified category consisted mainly of fine crab fragments and unidentified organic matter passing through a #4 sieve, but also included sand and mollusk shell fragments. Mollusks were also common food items (40.9% FO), but their dry mass contribution was low (1.6% DM). Vegetation occurred in 22.7% of the samples, but contributed only 0.1% to the total dry mass. Fish was the least common food item (1.5% FO, 0.0% DM) and was represented by a single specimen of tonguefish (Cynoglossidae).

There were 27 turtles < 40 cm MSCL (mean = 35.8 ± 3.2 cm) and 38 turtles > 40 cm MSCL (mean = 45.3 ± 3.6 cm). One turtle was omitted from the analyses because of severe damage to the posterior carapace. There were small trends in prey consumption between size classes (Table 2). Vegetation and unidentified categories had higher frequencies of occurrence in turtles > 40 cm, as did the live bottom and mollusk categories to a lesser degree. The frequency of *M. occidentalis* was slightly higher in the fecal samples of turtles > 40 cm, while worm tubes were slightly more

Table 2. Food items identified from Kemp's ridley turtle fecal samples (n = 66) captured in Gullivan Bay, Ten Thousand Islands, southwest Florida. The turtles were also separated into two groups based on carapace length (< 40 and > 40 cm), n = 65 (one turtle was omitted from the size classification due to carapace damage).

Category/taxa	% occurrence	% mass	% occurrence by size < 40 cm n = 27	% occurrence by size > 40 cm n = 38	% mass by size < 40 cm n = 27	% mass by size > 40 cm n = 38
Live bottom	83.3	38.6	77.8	86.8	37.6	39.0
Molgula occidentalis Traustedt, 1883	72.7	30.5	66.7	76.3	24.6	29.4
Worm tubes	40.9	1.0	48.1	36.8	1.2	0. 9
Unidentified soft-body organism	21.2	1.0	18.5	23.7	1.5	0. 7
Amathia sp.	10.6	0.1	14.8	7.9	0.0	0.1
Hydroid	6.1	0.0	11.1	2.6	0.0	0.0
Unidentified sponge	6.1	4.5	3.7	7.9	1.5	5.8
Encrusting bryozoan	4.5	0.2	7.4	2.6	0.3	0.1
Leptogorgia sp.	3.0	0.0	0.0	5.3	0.0	0.0
Encusting bryozoan/worm tube	1.5	1.5	0.0	2.6	0.0	2.1
Crabs	72.7	34.9	74.1	73.7	37.6	34.1
Libinia sp.	42.4	13.5	37.0	47.4	11.0	14.1
Persephona mediterranea (J.F.W. Herbst, 1794)	37.9	8.3	48.1	31.6	15.1	5.3
Unidentified crab	36.4	6.2	37.0	36.8	4.5	7.0
Hepatus epheliticus Linné, 1763	13.6	0.6	14.8	13.2	1.1	0.3
Limulus polyphemus Linnaeus, 1758	10.6	1.4	7.4	13.2	0.3	1.9
Pitho sp.	10.6	0.3	7.4	13.2	0.4	0.3
Hexapanopeus sp.	10.6	0.5	11.1	10.5	0.5	0.3
Menippe mercenaria (Say, 1818)	9.1	2.3	3.7	13.2	2.5	2.3
Petrochirus Diogenes Linné, 1758	7.6	0.3	3.7	10.5	0.2	0.4
Rithropanopeus harrisii Gould, 1841	6.1	0.2	7.4	5.3	0.1	0.2
Callinectes sapidus M.J. Rathbun, 1896	4.5	1.3	0.0	7.9	0.0	1.9
Pinnotheres maculates Say, 1818	4.5	0.0	3.7	5.3	0.0	0.0
Eurypanopeus depressus Smith, 1869	1.5	0.0	0.0	2.6	0.0	0.1
Unidentified	63.6	24.8	51.9	71.1	24.0	24.9
#200 unidentified	39.4	12.6	29.6	44.7	9.0	12.7
#200 sand/shell	22.7	9.9	22.2	23.7	11.5	9.3
#4 unidentified	10.6	2.3	3.7	13.2	0.3	3.0
Mollusks	40.9	1.6	37.0	42.1	0.8	2.0
Unidentified mollusk	30.3	0.5	33.3	28.9	0.6	0.4
Nassarius sp.	10.6	0.2	0.0	18.4	0.0	0.2
Marginella sp.	6.1	0.0	3.7	7.9	0.0	0.0
Anadara sp.	6.1	0.0	7.4	5.3	0.0	0.0
Crassostrea virginica Gmelin, 1791	4.5	0.0	0.0	7.9	0.0	0.1
Lucina sp.	4.5	0.0	3.7	5.3	0.0	0.1
Vermicularia sp.	1.5	0.0	3.7	0.0	0.0	0.0
Pleuroploca gigantea (Kiener, 1840)	1.5	0.7	0.0	2.6	0.0	1.1
Mollusk egg case	1.5	0.0	0.0	0.0	0.0	0.0
Vegetation	22.7	0.1	11.1	31.6	0.0	0.1
Thalassia testudinum Banks, 1805	10.6	0.0	7.4	13.2	0.0	0.0
Halodule wrightii Aschers., 1868	7.6	0.0	3.7	10.5	0.0	0.0
Unidentified algae	7.6	0.0	11.1	5.3	0.0	0.0
Syringodium filiforme Kuetz., 1860	4.5	0.0	3.7	5.3	0.0	0.0
Halophila engelmanii Aschers., 1875	3.0	0.0	0.0	5.3	0.0	0.0
Caulerpa prolifera Forsskal	3.0	0.0	0.0	5.3	0.0	0.0
Unidentified vegetation	3.0	0.0	0.0	5.3	0.0	0.0
Fish	1.5	0.0	0.0	2.6	0.0	0.0
Cynoglossid	1.5	0.0	0.0	2.6	0.0	0.0

frequent in turtles < 40 cm. *Libinia* sp. occurred more frequently in turtles > 40 cm and *P. mediterranea* more frequently in turtles < 40 cm. The percent dry mass of *P. mediterranea* was also higher in turtles < 40 cm. *Callinectes sapidus*, the prey most commonly associated with the Kemp's ridley, was only found in samples of turtles > 40 cm and the frequency of *Menippe mercenaria* Say, 1818 was higher for this size class as well. Only samples for turtles > 40 cm contained shells of *Nassarius* sp. and a single sample from this size class contained operculum fragments of *Pleuroploca gigantea* Kiener, 1840.

Discussion

Kemp's ridley turtles in Gullivan Bay are unique because they prey heavily on a benthic tunicate, which has not been reported in other dietary studies. The turtles in this region are essentially carnivorous grazers and did not consistently consume the commercial crab species commonly identified as prey, even though the waters offshore Gullivan Bay support a major stone crab fishery and both inshore and offshore waters support a minor blue crab fishery. However, relatively little of either of these food items was encountered in the present fecal analysis. This suggests that the Gullivan Bay ridleys may be opportunistically feeding on the more easily captured and possibly more abundant tunicates, although the availability of potential cancivorous prey (e.g., stone and blue crab) is not known in the locations where the turtles were captured. Shaver (1991) and Werner (1994) suggested that Kemp's ridleys were opportunistic feeders in south Texas and Texas-Louisiana waters, and that turtles take advantage of easily captured prey items whenever they are encountered. Similarly, two juvenile ridleys in New York were reported to have consumed large quantities of seahorses (*Hippocampus erectus* Perry, 1810), another easily captured prey (Burke et al., 1993a). Shaver (1991) suggested that the presence of the scavenging mud snails (*Nassarius*) in fecal samples might be due to the turtles feeding on discarded commercial fisheries (shrimping) by-catch, and Cannon (1998) reported that ridleys follow Texas shrimp boats in order to feed on discarded fish by-catch. Feeding on fisheries by-catch may be a common feeding strategy because studies have reported an abundance of commercially undesirable fish in the intestinal tracts of turtles collected near major commercial fisheries (Werner, 1994; Cannon, 1998; Frick and Mason, 1998). A similar feeding strategy has been reported for loggerheads (*Caretta caretta* Linnaeus, 1758) on the southeast U.S. coast (Shoop and Ruckdeschel, 1982). However, there were also relatively large numbers of mud snails in the diet of the ridley turtles in Gullivan Bay where there is an absence of commercial trawling. Because *Nassarius* only emerge from sand cover in response to scent or a disturbance in the sediment (Fotheringham and Brunenmeister, 1989), these snails may be disturbed by the ridleys when they are feeding nearby, emerge, and subsequently become ingested.

Live bottom was identified as the preferred habitat for some Kemp's ridleys in west-central Florida (Schmid et al., 2003) and there appears to be a similar affinity in the present study area. Turtles were sometimes caught over live bottom areas in Gullivan Bay, as evidenced by sessile organisms (sponges, bryozoans, gorgonians, polychaete worm tubes, pen shells (*Atrina* sp.), and tunicates) that periodically fouled the turtle net. The benthic tunicate *M. occidentalis*, an abundant ascidian species in the Gulf of Mexico (Young, 1989), was often entangled in the net and was the most common food item in the live bottom category. This tunicate has a leathery tunic that passed through the turtle's digestive system intact and was therefore a major contributor to the fecal mass. Many of the fecal samples had several large tunicates, while 16 samples had as many as 30–130 whole tunicates. This latter observation would seem to indicate that turtles were targeting tunicates rather than consuming them incidentally to other prey items. The unidentified soft-body organism in the live bottom category and the organic matter in the unidentified category may have been sea pork (*Amaroucium stellatum* Verrill, 1871), another abundant tunicate captured in the turtle net.

Worm tubes were also abundant in the Kemp's ridley fecal samples, although they accounted for very little of the total mass. This group was primarily composed of the small leathery tubes of sabellid worms, hence the relatively small mass, but also included parchment worm tubes (*Chaetopterus variopedatus* Renier, 1804) and fragments of shell-encrusted worm tubes (*Diopatra cuprea* Bosc, 1802). *Molgula occidentalis* and other live bottom organisms were observed attached to these latter worm tube species when extracted from the turtle net. Bryozoan-encrusted *Diopatra* tubes were the primary component of one fecal sample, and this sample contributed more to the overall fecal mass than the other samples with worm tubes combined (Table 2), suggesting this turtle was targeting shell-encrusted worm tubes. For the other samples, however, worm tubes were probably ingested incidentally with tunicates. The mollusk, and, to a lesser extent, vegetation categories were also well represented in the fecal samples, but in low quantities, indicating that they too may have been consumed incidentally while feeding on tunicates and/or crabs.

Spider crabs (*Libinia* sp.) and the purse crab, *P. mediterranea*, were the most abundant crab species in the Kemp's ridley fecal samples. Spider crabs have been reported as prey items from several other dietary studies (Shaver, 1991; Burke et al., 1993b, 1994; Frick and Mason, 1998; Morreale and Standora, 1998; Seney, 2003), as have purse crabs (Shaver, 1991; Werner, 1994; Canon, 1998; Seney, 2003). Both crabs are described as slow moving (Fotheringham and Brunenmeister, 1989) and would therefore be easy prey for foraging ridleys. *Persephona mediterranea* is a small crab (≤ 6 cm) that buries itself into shelly mud sediments (Williams, 1984) and has been collected in this substrate during benthic sampling surveys in Gullivan Bay (Schmid and Witzell, unpubl. data). *Libinia* sp. is a larger demersal crab (≥ 10 cm) and has been found in association with live bottom habitat in the study area. Other crabs identified as prey in the present study have been reported as inhabitants of live bottom communities. Mud crabs (*Hexapanopeus*, *Eurypanopeus*, and *Rithropanopeus*) are often abundant among sponge, hydroid, and bryozoan colonies (Gosner, 1978), and *Hexapanopeus* has been found among ascidians (Williams, 1984). The mussel crab (*Pinnotheres*) is commensal with *M. occidentalis* (Williams, 1984), parchment worms (Gosner, 1978; Fotheringham and Brunenmeister, 1989), and pen shells (Fotheringham and Brunenmeister, 1989).

Despite differences in measuring techniques, the mean size of Kemp's ridleys from Gullivan Bay (41.4 cm MSCL) is similar to the mean size of wild turtles stranded in south Texas (43.3 cm curved carapace length; Shaver, 1991). Turtles from both areas consumed a variety of crab species, and both spider and purse crabs were consumed in similar frequencies and quantities. However, portunid crabs had the highest frequency of occurrence (*C. sapidus*) and highest contribution to fecal mass (*Arenaeus cribarius* Lamarck, 1818) in Kemp's ridleys from south Texas. There was also a preponderance of portunid crabs in the reported diets of smaller turtles (33–36 cm straight carapace length) from the Texas-Louisiana border and from Virginia (Shaver, 1991; Werner, 1994; Seney, 2003). These observations have led to the suggestion that the distribution of Kemp's ridleys corresponds to that of portunid crabs (Hildebrand, 1982; Ogren, 1989). However, we concur with Shaver (1991) that the distribution of Kemp's ridleys is a function of all the crab species consumed, not just portunids, and further suggest that live bottom habitat is a contributing factor to the distribution of both predator and prey.

Many of the benthic organisms in the fecal matter of the Gullivan Bay ridleys are also considered prey for immature loggerhead turtles, *Caretta caretta* Linnaeus, 1758, (Dodd, 1988). There were loggerheads present in Gullivan Bay during this study but they were not nearly as numerous as ridleys (Witzell and Schmid, 2004). Hence, the competition for benthic prey between the two species was probably minimal.

Anthropogenic debris such as plastic was not found in any of the fecal samples from Gullivan Bay, although these materials were found in the fecal samples from New York (Burke et al., 1994) and Texas (Werner, 1994; Cannon, 1998; Shaver, 1998). These latter areas have a relatively high concentration of coastal development near the study sites and large commercial and industrial fleets that undoubtedly contribute to extensive coastal pollution. Commercial fishing and shipping traffic is not present in the immediate vicinity of Gullivan Bay, but there is considerable recreational fishing traffic from nearby coastal developments. Witzell and Teas (1994) reviewed the occurrence of ingested anthropogenic debris documented by the Sea Turtle Stranding and Salvage Network and found that ridleys ingested less debris than other turtle species. Bjorndal et al. (1994) speculated that Kemp's ridleys in Florida ingest less debris because they chase and consume more active prey than either the herbivorous green turtle or the loggerhead. This is in contrast to our findings that the primary prey of Gullivan Bay ridleys is sedentary. The lack of debris in the fecal samples may simply indicate a low availability for consumption.

The Gullivan Bay Kemp's ridleys prey on a wide variety of organisms, but are primarily tunicate grazers. The nearshore benthic habitat for Gullivan Bay generally consists of a flat sand/mud bottom with clumps of tunicates/tube worms scattered across the benthos, and small discrete live bottom areas. This habitat likely extends south through the entire Ten Thousand Islands to Florida Bay (111 km). Significant numbers of Kemp's ridleys observed in the area from Cape Romano to Lostmans River (76 km) (Witzell, unpubl. data) suggest that this entire area is a major developmental habitat for Kemp's ridleys in the Gulf of Mexico as speculated by Witzell and Schmid (2004). It is not known what changes might have occurred in the nearshore environment of Gullivan Bay as a result of redirection of water flow in upland areas during the 1960s and 1970s, when a series of large canals were dug to drain wetlands to provide land for development and farming. However, a multi-agency (federal/state/county/private) effort (South Florida Restoration Project) is currently underway to reestablish the original flow of freshwater through the Everglades along the southwest coast of Florida from Marco Island to Florida Bay. The redirection of water flow from the manmade canal system back to riparian and estuarine ecosystems could influence the tunicate population and thus the ridley/tunicate predator-prey relationship in Gullivan Bay.

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ADDRESSES: (W.N.W.) *National Marine Fisheries Service, 75 Virginia Beach Drive, Miami, Florida 33149. E-mail: <wayne.witzell@noaa.gov>.* (J.R.S.) *Cooperative Institute for Marine and Atmospheric Studies, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149.* PRESENT ADDRESS: *The Conservancy of Southwest Florida, 1450 Merrihue Drive, Naples, Florida 34102.*